



Accuracy of strokes and serves in para table tennis: a comparative analysis across integrated sport classes

Szymon Galas ^{1ABCDE}, Justyna Satławska ^{2AD}, Michalina Błażkiewicz ^{2CD},
Ziemowit Bańkosz ^{3A}, Andrzej Ochal ^{4D}, Jan M. Konarski ^{5D},
Beata Pluta ^{1ACDE}

¹ Faculty of Tourism and Recreation, Poznań University of Physical Education, Poland

² Faculty of Rehabilitation, The Józef Piłsudski University of Physical Education in Warsaw, Poland

³ Faculty of Physical Education and Sports, Wrocław University of Health and Sport Sciences, Poland

⁴ Department of Rehabilitation, Medical University of Warsaw, Poland

⁵ Department of Theory of Sport, Poznań University of Physical Education, Poland

Authors' Contribution: A – Study Design, B – Data Collection, C – Statistical Analysis, D – Manuscript Preparation, E – Funds Collection

Abstract: Background: Table tennis is a highly accessible sport practiced by individuals with various physical and intellectual impairments; however, limited research has examined how functional classification influences sport-specific technical performance. The aim of this study was to compare the precision of serves and strokes among male para table tennis players representing different integrated sport classes (1–5, 6–10, and 11). Methods: A total of 92 male athletes (age: 26.63 ± 14.31 years) participated in this cross-sectional study. Performance was evaluated using standardized tests assessing serve accuracy (Target Service Test, Extreme Side Service Test, Short Service Test), stroke precision (Alternate Push Test, Manual Quickness and Ability (Q&A) tests), and speed-related skills (Skill Speed and Displacement Speed tests). Due to non-normal data distribution, nonparametric statistical methods were applied. Between-group differences were analyzed using the Kruskal–Wallis test with post hoc Dunn–Bonferroni comparisons, while ordered trends across classes were examined using the Jonckheere–Terpstra test. Results: Significant differences were found between integrated sport classes for selected variables, with players in lower classes demonstrating higher serve precision, while those in higher classes showed superior performance in coordination and speed-related tests. The Jonckheere–Terpstra test revealed significant monotonic trends across all analyzed variables ($p < 0.001$), indicating systematic performance changes across classes. Conclusions: These findings emphasize the influence of functional classification on technical performance in para table tennis and support the need for classification-sensitive assessment tools.

Keywords: para table tennis; technical performance; stroke accuracy; service accuracy

Corresponding author: Szymon Galas, email: galas@awf.poznan.pl

Copyright: © 2026
by the authors.
Submitted for
possible open access
publication under the
terms and conditions
of the Creative
Commons Attribution
(CC BY) license
(<http://creativecommons.org/licenses/by/4.0/>).

Received: 19.03.2026; Accepted: 7.04.2026; Published online: 9.04.2026

Citation: Galas S, Satławska J, Błażkiewicz M, Bańkosz Z, Ochal A, Konarski JM, Pluta B. Accuracy of strokes and serves in para table tennis: a comparative analysis across integrated sport classes. Phys Act Rev 2026; 14(2): 57-67. doi: 10.16926/par.2026.14.21



INTRODUCTION

Table tennis is one of the most accessible sports and can be practiced independently of age, gender, body type, or level of physical and intellectual fitness [1-4]. Due to its relatively low equipment requirements and ability to adjust the exercise intensity, this discipline is widely applied in competitive sport, recreation, and health promotion activities [4,5]. Similarly to many disciplines, like swimming, basketball and rugby, table tennis is an important component of physical rehabilitation and social integration programmes for individuals with various functional limitations in many countries [5-9]. It is also a form of physical activity practised by people with physical and intellectual disabilities [10-13].

The growing number of athletes with diverse types and degrees of disability has led to the development of more precise sport classification systems. These systems aim to ensure fair competition by grouping athletes according to their functional ability level rather than solely based on medical diagnosis [6]. The current classification system in para table tennis comprises 11 classes, accounting for differences in functional abilities among both wheelchair users and standing players, including those with intellectual disabilities [5,12,14].

Classes 1–5 include athletes competing in wheelchairs. Classes 6–10 comprise standing athletes with physical impairments, while class 11 is designated for athletes with intellectual disabilities [6]. In this context, the adaptation of performance tests for para table tennis players, particularly those assessing the effectiveness of serves and strokes, appears essential for a better understanding of sport-specific performance in this population.

The accuracy of strokes and serves has become an increasingly important component of performance in para table tennis, as athletes must adapt their technical execution to the constraints imposed by various types of disability. Despite its relevance, the existing body of literature addressing these variables remains limited, particularly among para table tennis players [12,13,15]. Available studies rarely focus on the development of performance tests specifically designed for table tennis players [13,16]. Moreover, such tests have primarily been developed for Class 11 athletes and are typically applied as supplementary tools within broader research frameworks, especially those concerned with movement biomechanics, as is also common in studies involving able-bodied players [5,16-19].

To date, only a small number of studies have attempted to adapt existing stroke and serve accuracy tests [20,21] for athletes with disabilities, not only for Class 11 but also for Classes 1–10 [22-23]. Importantly, classification in Paralympic sport reflects varying levels of functional limitation, which may influence the ability to perform complex motor skills. Therefore, analysing differences in the execution of technical elements across sport classes may provide valuable insight into the impact of the type and severity of disability on the effectiveness of technical and tactical actions in para table tennis.

Accordingly, the aim of the present study was to compare the precision of shots and serves among Polish para table tennis players representing different sport classes. Based on a review of the literature [16,22-23] and practical experience, the following hypotheses were formulated:

- H1: Para table tennis players competing in classes 1–5 achieve significantly lower scores in tests assessing stroke accuracy compared to players from higher integrated sport classes. This may be due to functional limitations affecting factors such as arm reach or the height of the ball bounce above the table surface, which in turn may restrict rapid upper-limb movements and bilateral coordination necessary for efficient execution of fast stroke sequences. These limitations are expected to be particularly evident in the Displacement Speed FH&BH and Manual Quickness and Ability (MQA) FH and BH tests, which require movement in both vertical and horizontal planes relative to the table.

- H2: Players in classes 1–5 achieve significantly higher scores in tests assessing serve precision compared to players from higher integrated sport classes.

This may be explained by the fact that the serve, although a relatively static element of the game, plays a crucial tactical role, particularly in wheelchair table tennis. In this group, rallies are usually shorter, and point outcomes often depend on the effectiveness of the serve and the subsequent return.

MATERIAL AND METHODS

Participants

Only male players were included in the study due to the limited number of women participating in para table tennis in Poland. The sample comprised 92 male para table tennis players from sport classes 1 to 11, who were either members of the Polish senior national team or participants in the Polish Grand Prix for People with Disabilities in Table Tennis, both organized by the Polish Table Tennis Association. The mean age of the participants was 26.63 ± 14.31 years. Their average training experience in table tennis was 9.64 ± 8.17 years, and their mean weekly training volume was 5.49 ± 3.14 hours.

The main criteria for inclusion of players in the study were: written informed consent from parents or legal guardians (in the case of underage players), membership in the Polish national table tennis team or participation in Polish Grand Prix tournaments, possession of a valid Polish Table Tennis Association license (equivalent to accident insurance), a minimum of two years of training experience, declared absence of health contraindications preventing the performance of all planned special fitness tests, and a playing style requiring the use of a racket with smooth rubbers or, possibly, short pips. Players using non-standard rubbers (anti-spin rubbers or long pimples) were excluded from the study because their use is associated with a specific playing technique, different from topspin shots or undercut and flip shots.

All participants, and for those under 18 years of age, their parents, provided written informed consent after being fully informed about the study aims and procedures. The experimental protocol was approved by the Bioethics Committee of the Karol Marcinkowski Medical University, Poznań, Poland (No. 543/18). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Procedures

The research was carried out on six separate occasions in selected Polish cities (Figure 1). Although the study had a cross-sectional design, identical testing conditions were ensured during each session; all participants performed the tests on the same tables, prior to training or competition. This approach made it possible to examine a relatively large sample of 92 players, despite the total duration of all testing sessions amounting to approximately 50 hours, and the fact that not all athletes participated in every Polish Grand Prix tournament or national team training camp.

Serve precision, in accordance with International Table Tennis Federation (ITTF) regulations, was assessed using three tests: the Target Service Test, the Extreme Side Service Test, and the Short Service Test. The precision of undercut strokes was evaluated using the Alternate Push Test, while the accuracy of flip strokes was measured with the Manual Quickness and Ability (Q&A) forehand (FH) and backhand (BH) tests. Topspin stroke precision was assessed using the Skill Speed FH and BH tests, as well as the Displacement Speed FH&BH test.



Figure 1. Timeline of testing sessions (T1–T6) across study locations.

Before testing, all participants completed a standardized warm-up consisting of 15 minutes of general exercises to prepare for physical exertion, followed by a 20-minute sport-specific warm-up at the table under the supervision of a master-class coach. Prior to each trial, players received detailed instructions and performed five familiarization attempts. A one-minute recovery interval was provided between tests.

Service precision was evaluated using three tests proposed by Purashwani et al [21]: the Target Service Test, the Short Service Test, and the Extreme Side Service Test. In the Target Service Test, players executed three serves in accordance with ITTF rules, aiming at marked target areas on the opponent's side of the table. The outer rectangle (80 × 40 cm), located 12.5 cm from the net, was awarded 3 points, while the inner rectangle (30 × 15 cm) was awarded 5 points. For players in classes 1–5, the test was modified by relocating the target areas to the middle of the table [22], in accordance with wheelchair table tennis service regulations, which require the ball to leave the table beyond the end line after bouncing on the opponent's side.

In the Short Service Test, players aimed to land the ball in designated short service zones. A successful hit within 34.25 cm from the net was awarded 5 points, while a placement between 34.25 cm and 68.5 cm from the net scored 3 points. In the Extreme Side Service Test, servers were directed toward the lateral zones of the table. A hit along a line 15 cm from the side edge was awarded 5 points, while placement between this line and a line located 36.25 cm from the table's center axis scored 3 points.

The Alternate Push Test [21] was used to assess the precision of undercut strokes. The objective was to maintain a rally of undercut shots with a master-class coach while directing the ball between the net and a string positioned 20 cm above it. The test lasted 30 seconds. One point was awarded when the ball passed cleanly between the net and the string, half a point when it contacted the string, and zero points if it passed above it. The final result was the best score obtained from two trials.

Flip stroke precision was evaluated using the Manual Quickness and Ability FH and BH tests [20]. The objective was to execute straight-line flip strokes (attacking strokes performed over the table against short balls) into designated 30 × 30 cm target areas located 30 cm beyond the net. Only straight shots were considered valid. Players performed 15 strokes - forehand in the first test and backhand in the second - against balls delivered to a fixed location. For wheelchair athletes, the ball delivery point was adjusted to 45 cm beyond the net, in accordance with established adaptations [22].

Topspin precision was assessed using three tests: Skill Speed FH, Skill Speed BH, and Displacement Speed FH&BH [23]. The aim was to execute topspin strokes with pronounced forward rotation into a designated target area on the opponent's side of the table. Only diagonal shots were counted. The target zone measured 135 × 76 cm. In the first test, players performed forehand strokes; in the second, backhand strokes; and in the third, alternating forehand and backhand strokes. Each trial consisted of 20 balls delivered by a robot or server at a frequency of 80 balls per minute, corresponding to a duration of 15 seconds.

The testing protocols developed by Purashwani [21] were previously validated and adapted for players in classes 1–5 [22–23]. The rating scale used in the present study was adopted from research on able-bodied athletes solely to provide a comparative reference across genders. However, direct comparison with the classification scales proposed in [20] is limited, as these were developed exclusively for able-bodied players and do not account for gender differences.

Statistical Analysis

All statistical analyses were performed using Statistica software (version 13.3; TIBCO Software Inc., Palo Alto, CA, USA). The normality of data distribution was assessed using the Shapiro–Wilk test. As the majority of variables did not meet the assumption of normality, the data are presented as medians and interquartile ranges (Q1–Q3).

Differences in demographic and performance variables between integrated sport classes (1–5, 6–10, and 11) were examined using the Kruskal–Wallis test. When a significant main effect was observed ($p < 0.05$), post-hoc pairwise comparisons were performed using Dunn’s test with Bonferroni correction.

Effect sizes for the Kruskal–Wallis test were calculated using eta squared $\eta^2 = \frac{H-k+1}{N-k}$; where: H - Kruskal–Wallis statistic, k - number of groups ($k=3$), and N - total sample size ($N=92$). The magnitude of the effect size was interpreted as small (0.01), medium (0.06), and large (0.14) [24].

To examine ordered differences across the three performance groups (1–5 Class, 6–10 Class, and 11 Class), the Jonckheere–Terpstra test was applied. This test is specifically designed to detect monotonic trends across ordered groups. Given the ordinal nature of the grouping variable and the non-normal distribution of most variables, this approach was considered appropriate.

The test was conducted separately for each variable. The null hypothesis assumed no ordered trend across groups, while the alternative hypothesis tested for a statistically significant monotonic increase or decrease across the predefined group hierarchy. All analyses were performed using MATLAB R2021a (MathWorks Inc., Natick, MA, USA).

RESULTS

Between-Group Differences in Anthropometric, Training, and Performance Variables

Following the application of the Shapiro–Wilk test, deviations from normality were identified in the 1–5 Class group for Table tennis training experience [years], Training frequency per week [hours], Target Service Test [points/15], and Skill speed FH [number of hits/20]. In the 6–10 Class group, all variables exhibited non-normal distributions except for Skill speed FH [number of hits/20] and Displacement speed FH&BH [number of hits/20]. In the 11 Class group, only Training frequency per week [hours] and Displacement speed FH&BH [number of hits/20] deviated from normality. Therefore, nonparametric analyses were applied (Table 1).

A significant effect of group was observed for Age ($H(2) = 19.05$, $p = 0.01$, $\eta^2 = 0.19$), indicating a large effect size. Post hoc analysis revealed that the 1–5 Class group was significantly older than the 6–10 Class group ($p = 0.01$).

Significant differences were also found for the Target Service Test ($H(2) = 10.43$, $p = 0.01$, $\eta^2 = 0.09$). Post hoc comparisons indicated that the 1–5 Class group achieved higher scores than both the 6–10 Class and 11 Class groups ($p = 0.01$ for both comparisons).

Table 1. Between-Group Differences in Anthropometric, Training, and Performance Variables Presented as Median: Kruskal–Wallis Analysis with Effect Sizes and Dunn–Bonferroni Post Hoc Tests.

Variable	1-5 Class (N = 16)	6-10 Class (N = 63)	11 Class (N = 13)	H(2); p-value; effect size	Pairwise post-hoc tests
Age [years]	45; (33.75, 49.25)	19; (13, 30.5)	23; (21, 36)	19.05; 0.01*; 0.19	1-5 vs 6-10; 0.01*
Table tennis training experience [years]	10.5; (5.5, 16.5)	5; (3, 11)	12; (9, 14)	5.62; 0.06; 0.04	ns.
Training frequency per week [hours]	4.5; (3, 6)	5; (3, 7)	4; (4, 5)	0.27; 0.87; 0.02	ns.
Target Service Test [points/15]	13; (11, 13)	9; (8, 11)	9; (7, 11)	10.43; 0.01*; 0.09	1-5 vs 6-10 and 1-5 vs 11; 0.01*
Extreme Side Service Test [points/15]	10; (8.75, 13)	11; (8.5, 13)	9; (9, 13)	2.36; 0.31; 0.01	ns.
Short Service Test [points/15]	10; (7.75, 11.5)	10; (8, 11)	11; (8, 13)	1.33; 0.52; 0.01	ns.
Alternate Push Test [number of hits/30 s.]	22; (19, 23)	24; (22, 25.5)	23; (21, 24)	7.23; 0.02*; 0.06	1-5 vs 6-10; 0.01*
Manual Q&A FH [number of hits/15]	9; (5.75, 10.25)	11; (8.5, 13)	9; (5, 11)	9.37; 0.01*; 0.08	1-5 vs 6-10; 0.01*
Manual Q&A BH [number of hits/15]	9.5; (6.75, 10)	12; (10, 14)	11; (8, 12)	11.58; 0.01*; 0.11	1-5 vs 6-10; 0.01*
Skill speed FH [number of hits/20]	16.5; (10.75, 18)	14; (11.5, 17)	14; (12, 15)	1.2; 0.55; 0.01	ns.
Skill speed BH [number of hits/20]	13.5; (10.75, 16.25)	15; (12, 17.5)	12; (11, 14)	6.16; 0.05; 0.05	ns.
Displacement speed FH&BH [number of hits/20]	11.5; (6.75, 14)	11; (7.5, 14)	7; (5, 15)	0.16; 0.92; 0.02	ns.

H: Kruskal-Wallis Anova; *: statistical significance.

Furthermore, significant group differences were observed in the Alternate Push Test ($H(2) = 7.23$, $p = 0.02$, $\eta^2 = 0.06$), Manual Q&A FH ($H(2) = 9.37$, $p = 0.01$, $\eta^2 = 0.08$), and Manual Q&A BH ($H(2) = 11.58$, $p = 0.01$, $\eta^2 = 0.11$). In all cases, post hoc analyses showed that the 6–10 Class group performed significantly better than the 1–5 Class group ($p = 0.01$).

No statistically significant differences were found between groups for Table tennis training experience, Training frequency per week, Extreme Side Service Test, Short Service Test, Skill speed FH, Skill speed BH, or Displacement speed FH&BH ($p > 0.05$). Overall, the observed effect sizes ranged from negligible to large, with the strongest effect noted for Age. Moderate effects were identified for selected performance variables, particularly Manual Q&A BH and the Target Service Test.

Monotonic Trends in Anthropometric, Training, and Performance Variables: Jonckheere–Terpstra Analysis

The Jonckheere–Terpstra test revealed significant monotonic trends across all analyzed variables (all $p < 0.001$) (figure 1). A significant decreasing trend across groups was observed for age ($Z = -9.24$, $p < 0.001$), indicating that participants in higher classes were younger. Similarly, table tennis training experience ($Z = -7.50$, $p < 0.001$) and training frequency per week ($Z = -7.46$, $p < 0.001$) showed significant decreasing trends across groups. In contrast, a significant increasing trend was identified for multiple performance variables, including the Target Service Test ($Z = -9.60$, $p < 0.001$), Extreme Side Service Test ($Z = -7.50$, $p < 0.001$), and Short Service Test ($Z = -6.48$, $p < 0.001$), indicating progressively better service performance in higher classes.

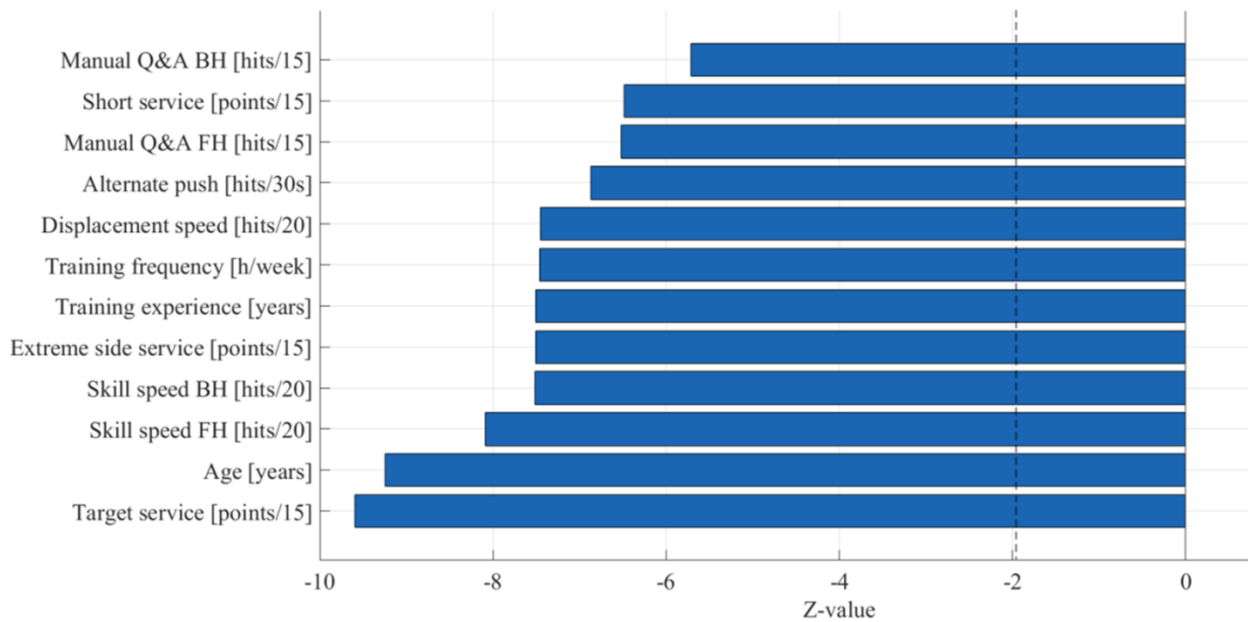


Figure 1. Jonckheere–Terpstra test results presented as Z-values for the analyzed variables, indicating significant monotonic trends across the three performance groups. The dashed horizontal lines indicate the critical values corresponding to $p = 0.05$.

Significant trends were also observed for coordination and speed-related variables, such as the Alternate Push Test ($Z = -6.86$, $p < 0.001$), Manual Q&A FH ($Z = -6.52$, $p < 0.001$), and Manual Q&A BH ($Z = -5.71$, $p < 0.001$).

Furthermore, significant trends were found for all speed-related measures, including Skill Speed FH ($Z = -8.09$, $p < 0.001$), Skill Speed BH ($Z = -7.51$, $p < 0.001$), and Displacement Speed FH&BH ($Z = -7.45$, $p < 0.001$), indicating systematic improvements in performance across higher classes.

DISCUSSION

The present study investigated differences in serve and stroke precision across para table tennis players representing different integrated sport classes, as well as monotonic trends across the classification system. The results provide a comprehensive overview of how functional classification influences technical performance in para table tennis and confirm the importance of classification-sensitive approaches in both research and practice. The Jonckheere–Terpstra analysis revealed significant monotonic trends across all analyzed variables ($p < 0.001$), indicating systematic and consistent changes in performance along the classification hierarchy. This finding aligns with the fundamental principles of Paralympic classification, which aim to ensure fair competition by grouping athletes according to their functional abilities rather than their medical diagnosis, International Paralympic Committee (<https://www.paralympic.org/classification>). The observed trends suggest that both the severity and type of impairment play a crucial role in shaping sport-specific performance capacities in para table tennis.

In relation to Hypothesis 1, which assumed that players in classes 1–5 would achieve lower stroke precision compared to higher classes, the findings partially confirm this assumption. Athletes in lower classes demonstrated significantly lower performance in tests requiring complex motor coordination and rapid execution, particularly in the Manual Quickness and Ability (Q&A) tests and the Alternate Push Test. These results can be attributed to functional limitations commonly observed in

wheelchair athletes, such as reduced trunk stability, limited range of motion, and impaired ability to generate fast and coordinated upper-limb movements. Such constraints directly affect the execution of strokes that require both precision and speed, especially in tasks involving bilateral coordination and rapid directional changes.

These observations are consistent with previous literature indicating that coordination and speed-related abilities are strongly influenced by the severity of physical impairment, which can limit the efficiency of movement patterns in adaptive sports (e.g., biomechanical analyses of wheelchair sports performance) [25,26] and are in line with research highlighting the role of neuromuscular control and postural stability in various sports performance [27-28].

Interestingly, not all stroke-related variables showed significant differences between classes, suggesting that certain technical skills may be more adaptable and less sensitive to functional limitations, possibly due to compensatory mechanisms developed through training and experience. This highlights the complexity of motor performance in para table tennis, where individual adaptations may partially offset physical constraints.

Regarding Hypothesis 2, which proposed that players in classes 1–5 would achieve higher serve precision compared to higher classes, the results confirmed this assumption. Athletes in lower classes achieved significantly higher scores in the Target Service Test, indicating superior serve accuracy. This finding may be explained by the tactical and structural characteristics of wheelchair table tennis, where rallies are generally shorter, and the serve plays a decisive role in determining the outcome of a point. In this context, players with limited mobility may rely more heavily on serve precision as a key competitive advantage, emphasizing placement, spin, and control rather than dynamic stroke exchanges.

The serve, being a relatively static and repeatable action, may allow athletes with greater functional impairments to effectively compensate for reduced mobility by focusing on technical precision and consistency. This interpretation is supported by previous studies in racket sports, which have highlighted the importance of serve effectiveness as a critical performance factor, particularly in constrained movement conditions, such as table tennis (see e.g., analyses of elite table tennis match performance and serve effectiveness) [14, 16, 29]. Therefore, the findings of the present study reinforce the notion that different technical components of the game may be differentially influenced by functional classification.

From a broader perspective, the observed differences and trends across integrated sport classes emphasize that classification is not only a system for ensuring fairness but also a meaningful predictor of performance in para table tennis. The significant monotonic relationships identified in all analyzed variables further confirm that performance characteristics change progressively with increasing functional ability. This is particularly evident in coordination and speed-related variables, where higher classes demonstrated superior performance, reflecting the greater physical capabilities and movement efficiency of these athletes. At the same time, the higher serve precision observed in lower classes suggests that athletes with greater functional limitations may develop specific technical strengths that allow them to remain competitive despite reduced mobility.

Study Limitation

Despite the strengths of this study, several limitations should be acknowledged. The sample included only male athletes, which limits the generalizability of the findings to female players and restricts the applicability of the results to mixed-gender contexts. Additionally, the cross-sectional design does not allow for causal inferences regarding the relationship between functional classification and performance outcomes, meaning that observed differences should be interpreted as associations rather than causal effects. Although standardized

testing procedures were applied, the laboratory-like conditions may not fully reflect the complexity of real match situations, where tactical, psychological, and environmental factors also play a significant role in determining performance. Furthermore, the relatively small number of participants within certain sport classes may limit the statistical power of some comparisons and should be considered when interpreting the findings. Future research should address these limitations by including female athletes, adopting longitudinal designs, and incorporating match analysis and biomechanical approaches to provide a more comprehensive understanding of performance differences across sport classes.

Practical Applications

The findings of this study have important practical implications for coaches, sport scientists, and classification experts working in para table tennis. The results highlight the need to develop classification-sensitive performance assessment tools that take into account the functional characteristics of athletes. Such tools should be designed to better reflect the physical capabilities and limitations associated with each sport class, allowing for more accurate evaluation of performance. In addition, training programs should be individualized according to the specific needs of athletes, with a greater emphasis on coordination, speed, and bilateral control in higher classes, while focusing more on serve precision, consistency, and tactical skills in lower classes. The implementation of classification-aware monitoring systems may further support athlete development by enabling more precise tracking of progress and more effective optimization of training interventions.

CONCLUSION

The present study demonstrates that functional classification has a significant impact on technical performance in para table tennis, with clear and consistent monotonic trends observed across all analyzed variables. Athletes in higher integrated sport classes showed superior performance in coordination and speed-related tasks, whereas athletes in lower classes achieved higher serve precision. These findings confirm that both the severity and type of impairment play a crucial role in shaping sport-specific performance and highlight the importance of classification-sensitive approaches in both research and applied sport settings. Overall, the results contribute to a better understanding of performance determinants in para table tennis and provide a basis for future research and practical applications aimed at optimizing athlete development.

Funding Statement: This research was funded by the Polish Table Tennis Association (PZTS).

Acknowledgments: The authors gratefully acknowledge the collaboration and support of the Polish Table Tennis Association (PZTS).

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

REFERENCES

1. Zagatto AM, Morel EA, Gobatto CA. Physiological responses and characteristics of table tennis matches determined in official tournaments. *J Strength Cond Res* 2010; 24: 942–949. doi: 10.1519/JSC.0b013e3181cb7003.
2. Macnamara A, Collins D. Do mental skills make champions? Examining the discriminant function of the psychological characteristics of developing excellence questionnaire. *J Sports Sci* 2013; 31: 736–744. doi: 10.1080/02640414.2012.747692.

3. Coelho ESMJ, Konarski JM, Krzykała M, Galas S, Beata P, Żurek P, Faria J, Tavares OM, Oliveira TG, Rodrigues I, et al. Growth and maturity status of young male table tennis players. *Res Sports Med* 2022; 30: 61–79. doi: 10.1080/15438627.2021.1888099.
4. Pluta B, Galas S, Krzykała M, Andrzejewski M. The motor and leisure time conditioning of young table tennis players' physical fitness. *Int J Environ Res Public Health* 2020; 17. doi: 10.3390/ijerph17165733.
5. Faber IR, Elferink-Gemser MT, Faber NR, Oosterveld FG, Nijhuis-Van der Sanden MW. Can perceptuo-motor skills assessment outcomes in young table tennis players (7–11 years) predict future competition participation and performance? An observational prospective study. *PLoS One* 2016; 11: e0149037. doi: 10.1371/journal.pone.0149037.
6. Tweedy SM, Vanlandewijck YC. International Paralympic Committee position stand—background and scientific principles of classification in Paralympic sport. *Br J Sports Med* 2011; 45: 259–269. doi: 10.1136/bjism.2009.065060.
7. Dehghansai N, Lemez S, Wattie N, Baker J. A systematic review of influences on development of athletes with disabilities. *Adapt Phys Act Q* 2017; 34: 72–90. doi: 10.1123/apaq.2016-0030.
8. Kuberski M, Musial A, Błażkiewicz M, Wąsik J. Determinants of 50 m front crawl performance in adolescent non-elite female swimmers: A longitudinal study. *J Funct Morphol Kinesiol* 2025; 10: 274. doi: 10.3390/jfmk10030274.
9. Kuberski M, Musial A, Chorozucho M, Konarski JM, Wąsik J. Longitudinal effects of aerobic training programme on body composition in non-elite adolescent female swimmers. *PeerJ* 2025; 13: e19456. doi: 10.7717/peerj.19456.
10. Moustakas L, Patzsch K. Table Tennis for Health and Wellbeing: A Rapid Scoping Review. *Sports*. 2026; 14(2):63. doi:10.3390/sports14020063
11. Van Biesen D, Mactavish JJ, Pattyn N, Vanlandewijck YC. Cognitive predictors of performance in well-trained table tennis players with intellectual disability. *Adapt Phys Act Q* 2016; 33: 324–337. doi:10.1123/APAQ.2015-
12. Van Biesen D, Mactavish JJ, Vanlandewijck YC. Comparing technical proficiency of elite table tennis players with intellectual disability: Simulation testing versus game play. *Percept Mot Skills* 2014; 118: 608–621. doi: 10.2466/15.30.PMS.118k21w5.
13. Yam J-W, Pan J-W, Kong P-W. Measuring upper limb kinematics of forehand and backhand topspin drives with IMU sensors in wheelchair and able-bodied table tennis players. *Sensors* 2021; 21: 8303.
14. Guarnieri A, Presta V, Gobbi G, Ramazzina I, Condello G, Malagoli Lanzoni I. Notational analysis of wheelchair Paralympic table tennis matches. *Int J Environ Res Public Health* 2023; 20. doi: 10.3390/ijerph20053779.
15. Caldwell M, De Luigi A. Wheelchair tennis and para-table tennis. 2018; pp. 201–217.
16. Kong PW, Ma CMS. Assessing table tennis technical proficiency in individuals with disabilities: A scoping review. *Appl Sci* 2024; 14: 4815.
17. Iino Y, Kojima T. Kinematics of table tennis topspin forehands: Effects of performance level and ball spin. *J Sports Sci* 2009; 27: 1311–1321. doi: 10.1080/02640410903264458.
18. Bańkosz Z, Winiarski S. Parameters of topspin forehand in table tennis and their inter- and intra-individual variability. *J Sports Sci Med* 2020; 19: 138–148.
19. Widodo H, Tomoliyus, Alim A. Battery test innovation for table tennis skills: Content validity. *J Hum Sport Exerc* 2024; 19: 451–460. doi: 10.55860/m24w9527.
20. Gomes F, Amaral ., Ventura A, Aguiar J. Table tennis specific test battery. *Int. J. Table Tennis Sci* 2000; 4: 11–18.
21. Purashwani P, Datta AK, Purashwani M. Construction of norms for skill test table tennis players. *Int J Table Tennis Sci* 2010; 6: 93–98.
22. Galas S, Andrzejewski M, Pluta B. Reliability of accuracy and precision tests for elite para table tennis players. *Adapt Phys Act Q* 2023; 41: 268–286. doi: 10.1123/apaq.2023-0053.
23. Galas S, Pluta B. Adaptation and validation of selected stroke accuracy tests for elite para table tennis players. *Acta Kinesiologica* 2025; 19: 61–69. doi: 10.51371/issn.1840-2976.2025.19.1.8.
24. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*; 1988.
25. Churton E, Keogh JW. Constraints influencing sports wheelchair propulsion performance and injury risk. *BMC Sports Sci Med Rehabil* 2013; 5: 3. doi: 10.1186/2052-1847-5-3.
26. Kędziołek J, Błażkiewicz M, Starczewski M, Galas S, Pluta B, Krzepota J. Kinematic analysis of para table tennis players' movement dynamics in response to alternating directional ball feeds. *Appl Sci* 2025; 15: 12680. doi: 10.3390/app152312680.
27. Niżnikowski T, Łuba-Arnista W, Arnista P, Porter JM, Makaruk H, Sadowski J, Mastalerz A, Niżnikowska E, Shaw A. An external focus of attention enhances table tennis backhand stroke

- accuracy in low-skilled players. *PLoS One* 2022; 17: e0274717. doi: 10.1371/journal.pone.0274717.
28. Kuberski M, Musial A, Choroszucho M. Longitudinal effects of swimming training on anthropometric characteristics in pre-adolescent girls. *Phys Act Rev* 2025; 13(1): 116-130. doi: 10.16926/par.2025.13.11
29. Fuchs M, Faber IR, Lames M. Game characteristics in elite para table tennis. *Ger J Exerc Sport Res* 2019; 49: 251-258. doi: 10.1007/s12662-019-00575-4.